09/806141
JC08 Rec'd PCT/PTO 27 MAR 2001

SPECIFICATION

TITLE

METHOD FOR CHARACTER SEPARATION IN TEXT RECOGNITION TASKS

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a method for character separation in text recognition tasks.

Description of the Related Art

In the automatic recognition of texts, that is to say when converting the graphic information of a document into text characters which can be further processed by means of electronic text processing programs, an essential precondition for a successful recognition operation is the precise determination of the position and the size of the individual characters. In the case of originals with poor lettering or fonts with a very narrow character space, this determination is problematic, inter alia, in that the characters are interconnected and "grow together", and can therefore no longer be separated using conventional methods such as simple contour tracking.

SUMMARY OF THE INVENTION

The invention is therefore based on the object of specifying an improved method for separating interconnected characters.

This is performed according to the invention with the aid of a method in which possible points of intersection are determined in relation to the extraction objects

under examination by means of white space analysis and angle analysis, in which plausible separating lines are determined from the points of intersection and corresponding mating points, and in which objects separated in such a way are subjected to a classification process and the final separation is performed on the basis of the results.

A refinement of the method in which when there are more than three possible points of intersection, a first section is performed through the point of intersection selected fourth from the left-hand start of the character is advantageous. The reason for this is because no conventional text character of the Latin script has more than three white spaces.

It is also favorable when after a first section with a first possible point of intersection and a subsequent unsuccessful attempt at classification, the left-hand neighboring point of intersection situated closest to the first possible point of intersection is provided as basis for a further attempt at separation.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an illustration relating to the white space analysis of an image.

Figure 2 shows an illustration relating to the actual character separation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The sequence of the method according to the invention is as follows:

The method is started in the recognition operation after the determination of the position of the line. A white space analysis is already carried out when determining the circumference of a character or a plurality of connected characters by contour tracking. An angle analysis is performed after the complete contour is available.

White space analysis and angle analysis are used to determine possible points of intersection, which supply possible separating lines in conjunction with mating points.

The points of intersection are examined with regard to their plausibility/possibility. Which character sequences contain the present combination of white spaces is determined in the process. Thus, for example, the following white spaces are contained in the letter sequence **WV**: TOP-BOTTOM-TOP-BOTTOM-TOP. Here, TOP (BOTTOM) characterizes the white space which is open at the top (bottom). The knowledge of the letters is now used to perform the first separation through the point of intersection of the fourth white space.

It is determined thereupon to what extent the separation of the object along the separating lines touching at plausible points of intersection leads to plausible classification results. In other words, the separated characters or parts of characters are subjected to a recognition operation, for example by means of neural network and the separation is accepted if this operation leads to a satisfactory result - a character recognized with high reliability. Otherwise, the separation is repeated along other separation lines until there is a satisfactory result.

Neural networks are mathematical models which simulate the structure of the human brain. They comprise neurons, which are essentially summing elements with

weighted inputs and a nonlinear amplifier component which are combined to form a parallel network having typically two levels. A detailed description of the feed forward neural networks used in the exemplary embodiment is to be found, for example, in "Layered Neural Nets for Pattern Recognition", B. Widrow, R.G. Winter, R.A. Baxter; IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. 36, No. 7, July 88.

Pattern recognition by means of a neural network is performed using the method described in "A rotation, scaling, and translation invariant pattern classification system", C. Yüceer, K. Oflazer; Pattern Recognition, Vol. 26, No. 5, pp. 687-710, 1993.

The white space analysis is described in more detail with the aid of figure 1. The figure shows the two interconnected letters **r** and **f**, which have a white space W. Here, white space W means a white interspace bounded on three sides which has a certain depth and whose open side is directed upward or downward. This white space W is determined in the tracking of the contour of the character (which has grown together) when the contour line C transgresses two prescribed threshold values SW in both directions. If, as in the example, there is a white space W which is open downward, the highest point of the contour line C is defined as a possible point of intersection S, this being the lowest point in the case of a white space which is open upward.

The sequence of the angle analysis performed thereupon is as follows:

two vectors for which it holds that:

$$\overline{A} = C[i]C[i-5] \text{ and } \overline{B} = C[i]C[i+5]$$

are determined from in each case three points on the contour line C[i].

The angle between the two vectors is calculated. The angle is entered into a list if it is right-to-left with an absolute value of less than 80° and a vertex (C[i]) either upward or downward.

If this condition is fulfilled for a plurality of juxtaposed vector pairs, only the angle with the smallest absolute value is tracked further.

The angles entered in the list are now examined as to whether an angle of opposite orientation to the vertex is present on the opposite side of the contour line. If this is the case, the angle pair formed thereupon is stored as the position of a possible point of intersection.

The sequence in the determination of the angle between two vectors which are defined by the three points from the contour line (C_1:x1/y1, C_6:x2/y2, C_{11}:mx/my) is described below. The x and y components of the two vectors are determined therefrom.

Ax = x1-mx; Ay = y1-my; Bx=x2-mx; By=y2-mx.

The angle between the vectors A and B is calculated as follows: firstly, the angle of A to the x-axis is determined, and then the angle B to the x-axis.

Angle = arccos $\dfrac{\bar{A}x}{\sqrt{(\bar{A}x^2)+(\bar{A}y^2)}}$

$$\textit{Angle (in degrees)} = \frac{\textit{Angle (inRad)} * 180}{Pi}$$

Angle = 360-angle B+angle A (if the angle is greater than 360°, the angle is corrected by 360°).

The determination of the direction of the angle vertex is based on the consideration that in the case of a downward directed vertex the y-coordinates of the points C_1 and C_6 are smaller than the y-coordinate of C_{11}.

In the case of an upwardly directed vertex, the y-coordinates of the points C_1 and C_6 must be greater than the y-coordinate of C_{11}.

The characteristics of the printed text and the influence of the limited image resolution necessarily mean that, as a function of the space under consideration, in the region of a kink in the contour of a character that the angles, determined in the way described, between 2 vectors firstly become increasingly smaller and thereafter continuously increase again. Consequently, only the respectively minimum angle of such a range is used for the further evaluation.

In order to fix a possible separating line, it is now necessary to determine for each possible point of intersection C(Nr) a corresponding mating point on the opposite branch of the contour line C(i);i=(0,., contour Nr).

For this purpose, a straight line is laid through two points C(Nr-1) and C(Nr+1) adjacent to the possible point of intersection C(Nr) on the contour line, and the normal to this straight line is determined. The points adjacent to the point of intersection of this

normal with the opposite branch of the contour line are examined with regard to their spacing value from the possible point of intersection and the normal, and the contour point with the minimum spacing value is defined as mating point C(g), and thus as second point of the possible separating line. The mathematical definition of this operation is as follows:

nx=C(Nr+1)x-C(Nr-1)x

ny=C(Nr+1)y-C(Nr-1)y

Spacing = $\sqrt{(C(Nr)x-C(i)x)^2+(C(Nr)y-C(i)y)^2}$

spacing relative to g^2

$$=abs\left(\frac{nx^*(C(i)x-C(Nr)x)+ny^*(C(i)y-C(Nr)y)}{\sqrt{(nx^2+ny^2)}}\right)$$

spacing value = spacing + spacing relative to g^2;

C(g) = C(i) | spacing value (C(g), C(Nr)) = min

The actual separation is explained with the aid of figure 2, the basis of the separation is the contour line of the extracted character. In a first step, a separating line buffer is initialized with 0, and this corresponds to a perpendicular line at the left-hand edge, and thereafter the point on the contour line 1 between 0 and the point of intersection (the X-value maximum) on which the separation is based which is situated

furthest to the right is determined. The point on the branch (the x-value maximum) of the contour line from the mating point up to the end of the contour 2 and the separating line 3 which is situated furthest to the right is also determined.

The maximum x-values collected therefore constitute the extreme right-hand edge of the character used for the classification.

Although other modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

Method for character separation in text recognition tasks

The invention relates to a method for character separation in text recognition tasks.

In the automatic recognition of texts, that is to say when converting the graphic information of a document into text characters which can be further processed by means of electronic text processing programs, an essential precondition for a successful recognition operation is the precise determination of the position and the size of the individual characters. In the case of originals with poor lettering or fonts with a very narrow character space, this determination is problematic, inter alia, in that the characters are interconnected and "grow together", and can therefore no longer be separated using conventional methods such as simple contour tracking.

The invention is therefore based on the object of specifying an improved method for separating interconnected characters.

This is performed according to the invention with the aid of a method of the type mentioned at the beginning, in which possible points of intersection are determined in relation to the extraction objects under examination by means of white space analysis and angle analysis, in which plausible separating lines are determined from the points of intersection and corresponding mating points, and in which objects separated in such a way are subjected to a classification process and the final separation is performed on the basis of the results.

A refinement of the method in which when there are more than three possible points of intersection, a first section is performed through the point of intersection selected fourth from the left-hand start of the

character is advantageous. The reason for this is because no conventional text character of the Latin script has more than three white spaces.

It is also favorable when after a first section with a first possible point of intersection and a subsequent unsuccessful attempt at classification, the left-hand neighboring point of intersection situated closest to the first possible point of intersection is provided as basis for a further attempt at separation.

The invention is explained in more detail with the aid of figures in which, by way of example:

Figure 1 shows an illustration relating to the white space analysis of an image, and

Figure 2 shows an illustration relating to the actual character separation.

The sequence of the method according to the invention is as follows:

The method is started in the recognition operation after the determination of the position of the line. A white space analysis is already carried out when determining the circumference of a character or a plurality of connected characters by contour tracking. An angle analysis is performed after the complete contour is available.

White space analysis and angle analysis are used to determine possible points of intersection, which supply possible separating lines in conjunction with mating points.

The points of intersection are examined with regard to their plausibility. Which character sequences contain the present combination of white spaces is determined in the process. Thus, for example, the following white spaces are contained in the letter sequence **WV**: TOP-BOTTOM-TOP-BOTTOM-TOP. Here, TOP (BOTTOM) characterizes the white space which is open at the top (bottom). The knowledge of the letters is now used to perform the first separation through the point of intersection of the fourth white space.

It is determined thereupon to what extent the separation of the object along the separating lines touching at plausible points of intersection leads to plausible classification results. In other words, the separated characters or parts of characters are subjected to a recognition operation, for example by means of neural network and the separation is accepted if this operation leads to a satisfactory result - a character recognized with high reliability. Otherwise, the separation is repeated along other separation lines until there is a satisfactory result.

Neural networks are mathematical models which simulate the structure of the human brain. They comprise neurons, which are essentially summing elements with weighted inputs and a nonlinear amplifier component which are combined to form a parallel network having typically two levels. A detailed description of the feed forward neural networks used in the exemplary embodiment is to be found, for example, in "Layered Neural Nets for Pattern Recognition", B. Widrow, R.G. Winter, R.A. Baxter; IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. 36, No. 7, July 88.

Pattern recognition by means of a neural network is performed using the method described in "A rotation, scaling, and translation invariant pattern classification system", C. Yüceer, K. Oflazer; Pattern Recognition, Vol. 26, No. 5, pp. 687-710, 1993.

The white space analysis is described in more detail with the aid of figure 1. The figure shows the two interconnected letters **r** and **f**, which have a white space W. Here, white space W means a white interspace bounded on three sides which has a certain

depth and whose open side is directed upward or downward. This white space W is determined in the tracking of the contour of the character (which has grown together) when the contour line C transgresses two prescribed threshold values SW in both directions. If, as in the example, there is a white space W which is open downward, the highest point of the contour line C is defined as a possible point of intersection S, this being the lowest point in the case of a white space which is open upward.

The sequence of the angle analysis performed thereupon is as follows:

two vectors for which it holds that:

$\overline{A} = C[i]C[i-5]$ and $\overline{B} = C[i]C[i+5$

are determined from in each case three points on the contour line C[i].

The angle between the two vectors is calculated. The angle is entered into a list if it is right-to-left with an absolute value of less than 80° and a vertex (C[i]) either upward or downward.

If this condition is fulfilled for a plurality of juxtaposed vector pairs, only the angle with the smallest absolute value is tracked further.

The angles entered in the list are now examined as to whether an angle of opposite orientation to the vertex is present on the opposite side of the contour line. If this is the case, the angle pair formed thereupon is stored as the position of a possible point of intersection.

The sequence in the determination of the angle between two vectors which are defined by the three points from the contour line (C_1:x1/y1, C_6:x2/y2, C_{11}:mx/my) is described below. The x and y components of the two vectors are determined therefrom.

Ax = x1-mx; Ay = y1-my; Bx=x2-mx; By=y2-mx.

The angle between the vectors A and B is calculated as follows: firstly, the angle of A to the x-axis is determined, and then the angle B to the x-axis.

$$\textbf{Angle} = \arccos \frac{\bar{A}x}{\sqrt{(\bar{A}\,x^2)+(\bar{A}y^2)}}$$

$$\textbf{Angle (in degrees)} = \frac{\textbf{Angle(in Rad)*180}}{\textbf{Pi}}$$

Angle = 360-angle B+angle A (if the angle is greater than 360°, the angle is corrected by 360°).

The determination of the direction of the angle vertex is based on the consideration that in the case of a downward directed vertex the y-coordinates of the points C_1 and C_6 are smaller than the y-coordinate of C_{11}.

In the case of an upwardly directed vertex, the y-coordinates of the points C_1 and C_6 must be greater than the y-coordinate of C_{11}.

The characteristics of the printed text and the influence of the limited image resolution necessarily mean that, as a function of the space under consideration, in the region of a kink in the contour of a character that the angles, determined in the way described, between 2 vectors

firstly become increasingly smaller and thereafter continuously increase again. Consequently, only the respectively minimum angle of such a range is used for the further evaluation.

In order to fix a possible separating line, it is now necessary to determine for each possible point of intersection C(Nr) a corresponding mating point on the opposite branch of the contour line C(i);i=(0,., contour Nr).

For this purpose, a straight line is laid through two points C(Nr-1) and C(Nr+1) adjacent to the possible point of intersection C(Nr) on the contour line, and the normal to this straight line is determined. The points adjacent to the point of intersection of this normal with the opposite branch of the contour line are examined with regard to their spacing value from the possible point of intersection and the normal, and the contour point with the minimum spacing value is defined as mating point C(g), and thus as second point of the possible separating line. The mathematical definition of this operation is as follows:

nx=C(Nr+1)x-C(Nr-1)x

ny=C(Nr+1)y-C(Nr-1)y

$$\text{Spacing} = \sqrt{(C(Nr)x - C(i)x)^2 + (C(Nr)y - C(i)y)^2}$$

spacing relative to g^2

$$= abs\left(\frac{nx*(C(i)x - C(Nr)x) + ny*(C(i)y - C(Nr)y)}{\sqrt{(nx^2 + ny^2)}}\right)$$

spacing value = spacing + spacing relative to g^2;

C(g) = C(i)| spacing value (C(g), C(Nr)) = min

The actual separation is explained with the aid of figure 2, the basis of the separation is the contour line of the extracted character. In a first step, a separating line buffer is initialized with 0, and this corresponds to a perpendicular line at the left-hand edge, and thereafter the point on the contour line 1 between 0 and the point of intersection (the X-value maximum) on which the separation is based which is situated furthest to the right is determined. The point on the branch (the x-value maximum) of the contour line from the mating point up to the end of the contour 2 and the separating line 3 which is situated furthest to the right is also determined.

The maximum x-values collected therefore constitute the extreme right-hand edge of the character used for the classification.